Award Number: W81XWH-09-1-0395

TITLE: Control Interfaces for Human-Robot Interactions

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REPORT DATE: January 2011

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT:

Approved for public release; distribution unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
01-01-2011

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
15 MAY 2009 - 31 DEC 2010

4. TITLE AND SUBTITLE
Control Interfaces for Human-Robot Interactions

5a. CONTRACT NUMBER

5b. GRANT NUMBER
W81XWH-09-1-0395

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AnthroTronix, Inc.
Silver Spring, MD 20910

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
In recent years, extensive advances have been made in the development of military robotic systems for such applications as reconnaissance, surveillance, target acquisition, explosive ordinance disposal, and casualty extraction. Artificial intelligence has increased the autonomy level of such systems, while the integration of payloads has expanded the tasks they can perform. Ideally, a robotic platform would be capable of continuous, autonomous navigation in a variety of environments. However, this ability has not yet been fully demonstrated. Thus, human-robot interaction is necessary;but while much attentionhas been paidto robotic platforms, relatively little research and development has been dedicated to control interfaces for such systems. Effective interfaces for dismounted warfighters would minimize added load and complexity, potentially even integrated into existing gear. Specifically for casualty battlefield extraction, if a robot such as the BEAR were to be utilized, the warfighters would optimally have full control capabilities (discrete and proportional control commands) at-the-ready. Therefore, there is potentially widespread application of a navigation control unit that includes an instrumented gesture recognition glove and an M4-mounted isometric grip controller.Optimization of the HRI for the dismounted warfighter will not only increase the efficiency of the robotic casualty extraction but also help prevent the robot operator from becoming a casualty himself.

15. SUBJECT TERMS
human-robot interaction, casualty extraction, instrumented glove, iGlove, gesture recognition, Mounted Force Controller, gamepad, BEAR

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	18	USAMRMC
					19b. TELEPHONE NUMBER *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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Introduction

This project focused on integrating its previously developed advanced operator control unit interfaces (M4 rifle grip (“Mounted Force Controller”) and iGlove) for JAUS robots with the TRADOC OneSAF simulation systems for use with user evaluation of TATRC and RSJPO robots at the USA Infantry Center Maneuver Battle Lab (MBL), in particular for JGRE-funded virtual and live experimentation with the Battlefield Extraction-Assist Robot (BEAR). The objectives of the effort were as follows:

1. Provide and integrate an upgraded Instrumented Glove (iGlove) and Mounted Force Controller (MFC) with a JAUS-compliant robotic simulator.
2. Integrate weapons-MFC and iGlove with the Maneuver Battle Lab BEAR simulator.
3. Develop easily configurable Operator Control Unit (OCU) Graphical User Interface (GUI) for switching between best controller mapping for accomplishing certain tasks (e.g. Driving or Manipulation mode) using either the MFC or iGlove.
4. (Not in SOW) Support comparative controller testing at the Fort Benning Maneuver Battle Lab.

Body

Objective 1: Provide and integrate an upgraded Instrumented Glove (iGlove) and Mounted Force Controller (MFC) with a JAUS-compliant robotic simulator.

- Designed, fabricated, and assembled new wireless MFC electronics.
- Performed JAUS-compliant integration of iGlove & MFC with AnthroTronix’ unmanned ground vehicle (UGV) simulator.

Under this Objective, we upgraded the printed circuit boards (PCBs) for the Mounted Force Controller (MFC), improving reliability and battery charging characteristics. Silkscreen images of the PCBs are displayed below.

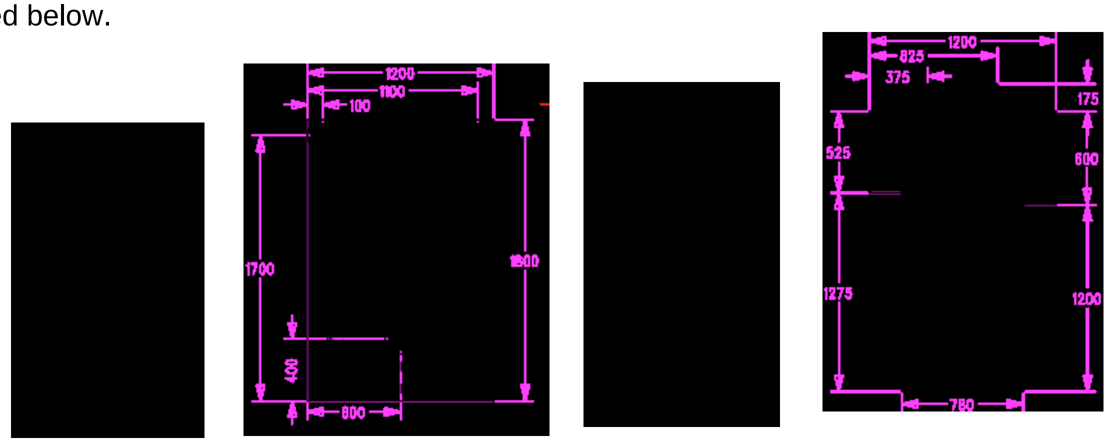


Figure 1. Updated Bluetooth wireless MFC printed circuit board silkscreens.

Figure 2. Updated MFC electronics being assembled (left) and MFC graphic (right).

Under Objective 1, we also provided our updated iGlove, which is also known as the AcceleGlove, for controller testing at the Fort Benning Maneuver Battle Lab.

Figure 3. AnthroTronix iGlove.

The iGlove and MFC controllers were then integrated with our existing JAUS-compliant unmanned ground vehicle (UGV) simulator (see Figure 4). This effort greatly simplified the subsequent BEAR simulator integration effort (see Objective 2 below).

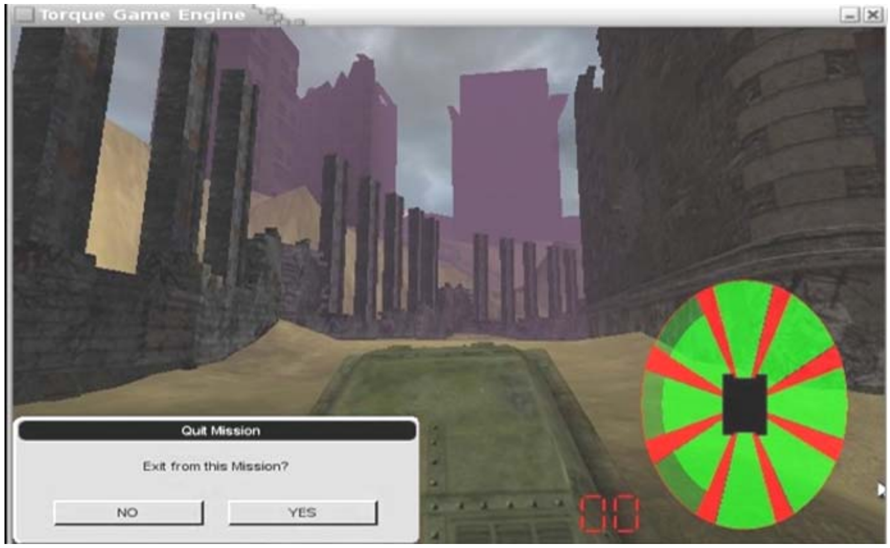


Figure 4. AnthroTronix JAUS-compliant robot simulator.

Objective 2: Integrate weapons-MFC and iGlove with the Maneuver Battle Lab BEAR simulator.

AnthroTronix conducted a two-phase integration of its controllers, via its JAUS-compliant operator control unit (OCU), with the Maneuver Battle Lab BEAR simulator. Phase 1 comprised an integration with the standalone Vecna BEAR simulator. Phase 2 comprised an on-site integration effort at the Fort Benning Maneuver Battle Lab.

The initial integration with the standalone BEAR simulator occurred at AnthroTronix' facilities with remote technical assistance from Vecna. Once this integration was performed, it allowed AnthroTronix to conduct controller testing and OCU modifications prior to the Fort Benning trip.

AnthroTronix personnel then traveled to Fort Benning, GA, and participated in a weeklong effort to integrate components that were to be included in the following week's controller user testing. The integration effort took place from 30 Nov – 4 Dec 2009. AnthroTronix personnel primarily assisted with integrating the iGlove and MFC operator control unit (OCU) interface with those of the TRADOC OneSAF and Vecna BEAR simulations. The overall integration was simplified due to the previous integration of AnthroTronix' OCU with the standalone BEAR simulation (see Objective 1 above).

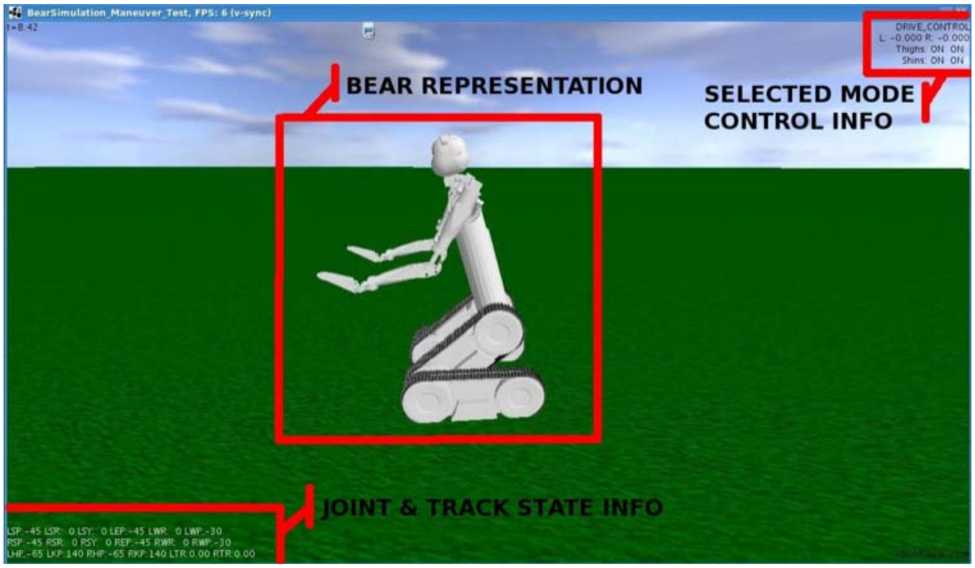


Figure 5. Labeled screenshot from the standalone BEAR robot simulation.

Objective 3: Develop easily configurable Operator Control Unit (OCU) Graphical User Interface (GUI) for switching between best controller mapping for accomplishing certain tasks (e.g. Driving or Manipulation mode) using either the MFC or iGlove.

We then developed a simple, easily configurable graphical user interface (GUI) to assist the user with interfacing the MFC and iGlove with the BEAR simulation. The GUI was designed to be intuitive, providing non-technical operators with a straightforward method for modifying the control system configurations. A screenshot of the GUI is displayed below.

Objective 4: Support comparative controller testing at the Fort Benning Maneuver Battle Lab*.

(*Note: Additional to SOW.)

BEAR Controller Testing
Fort Benning, GA – USA Infantry Center Maneuver Battle Lab (MBL)
7 – 11 Dec 2009

<u>Controllers</u>

Three different controllers were compared during testing at the Fort Benning Maneuver Battle Lab in November and December of 2009. Soldiers used the controllers to control a simulated BEAR robot in a virtual environment, performing specific tasks, including terrain navigation and picking up wounded soldiers, used the controllers. The three controllers used were an (see graphic below):

1. iGlove,
2. Mounted Force Controller (MFC), mounted to an Airsoft rifle, and
3. Logitech gamepad.

Controller	Image
iGlove	
Mounted Force Controller (MFC) (shown mounted to an Airsoft M-4 rifle)	
Gamepad	

Three “testing caves” were setup in the Maneuver Battle Lab to test different control scenarios. The three caves were setup next to each other, in a row. Each cave was designed to fully immerse the individual soldier in the virtual environment, which was displayed on a projector screen, which made up one of the cave walls (see figures below).

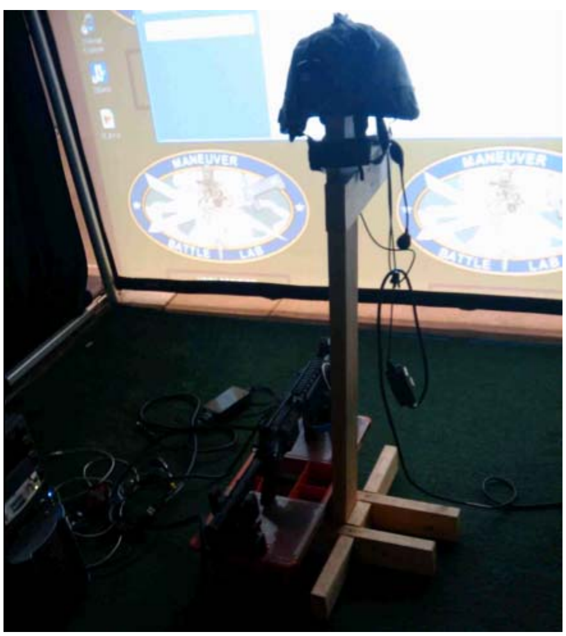


Figure 6. Inside on of the controller testing caves.

Figure 7. Soldier controller BEAR with the MFC in Cave #2.

Figure 8. Another soldier controlling BEAR with the MFC.

Figure 9. Front side of the 3 controller testing caves.

Controllers were used in the caves per the following assignment:

Cave 1: iGlove
Cave 2: iGlove + Mounted Force Controller
Cave 3: Gamepad

- In Cave 1, the iGlove was used to provide all control inputs to the BEAR.
- In Cave 2, the iGlove was used to switch control modes (via discrete hand signal recognition) and the MFC was used to provide proportional movement control inputs.
- In Cave 3, a Logitech gamepad was used to provide all control inputs to the BEAR.

Functionality and control input mappings for each of the controllers are outlined in Appendix A.

Key Research Accomplishments

- Designed, fabricated, and assembled new wireless MFC electronics.
- Completed updated iGlove (aka “AcceleGlove”) product.
- Performed JAUS-compliant integration of iGlove & MFC with BEAR simulator.
- Completed comparative user testing of iGlove, MFC, and gamepad as control inputs to the BEAR robot with soldiers at the Ft. Benning Maneuver Battle Lab.

Reportable Outcomes

- TATRC OASIS Demonstration, 17-18 June 2009, Fort Detrick, MD

Conclusion

Results from the controller testing at Fort Benning were mixed, yet promising. The soldiers found the iGlove and MFC more intuitive than thegamepad: they liked that simple, easy to remember hand gestures changed control modes (e.g., touching the hip to enter “Hip Mode”). The soldiers also reported that they would have liked to have more control options with both. For instance, they thought they could have used the two pushbuttons on the MFC in certain control situations. However, the

pushbuttons were not mapped to any functionality for the testing; instead, the iGlove was used to complement the MFC's capabilities in Cave #2. Follow-up testing with a more highly enabled MFC and iGlove would likely provide a clearer picture of the soldiers' impressions of the devices' utility.

References

None.

Appendices

Appendix A – Controller Functionality and BEAR Input Mappings

iGlove-BEAR Mappings – Mode Selection (Caves 1 & 2)

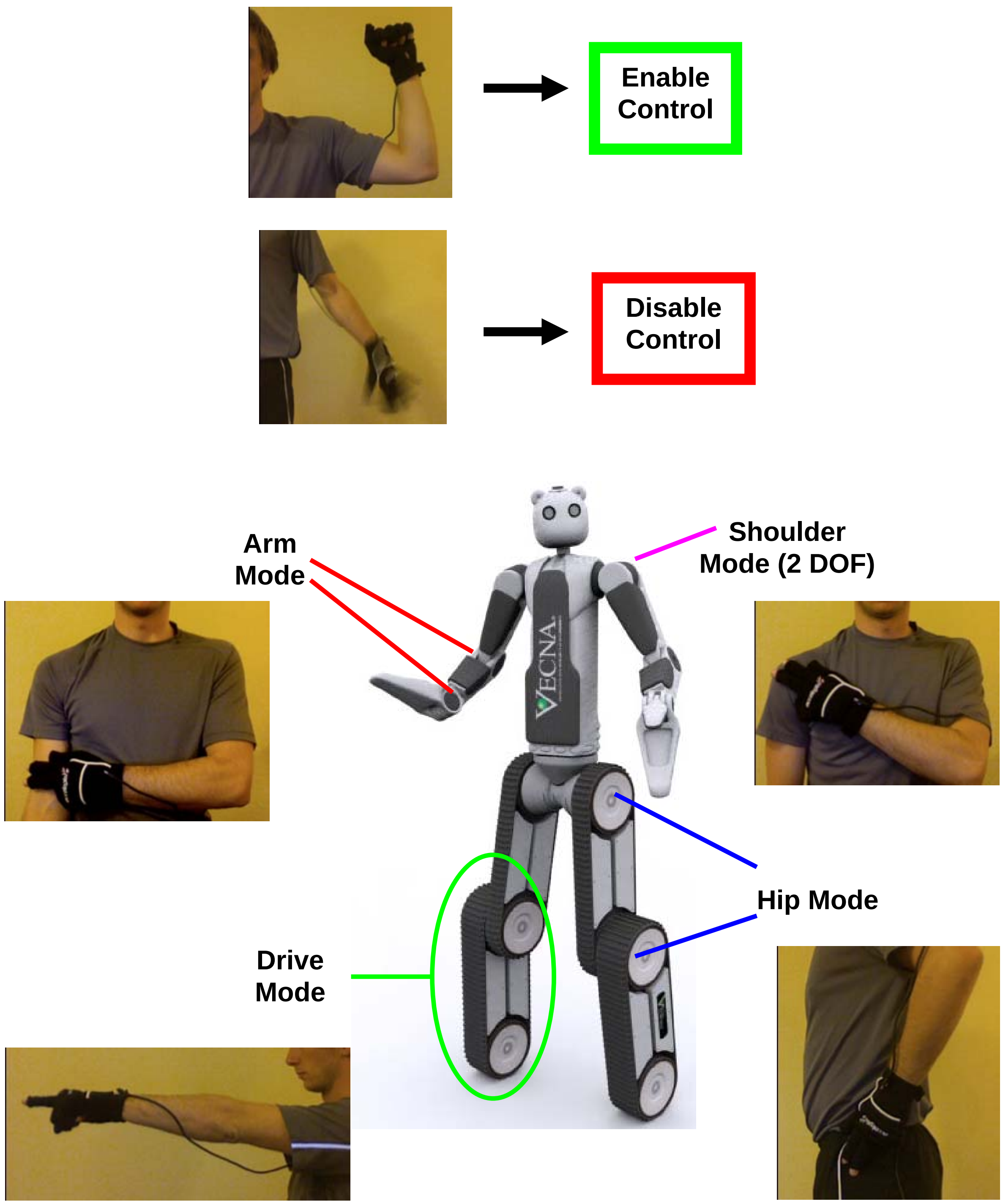


Figure 10. BEAR mode switching iGlove gestures.

iGlove-BEAR Mappings – Movement (Cave 1 only)

In Cave 1, the iGlove was used for both mode switching and joint / tracks control. Joint / tracks movement ocurred in response to two different glove positions:

1. Wrist pitch
   a. Bending at the wrist (flexion / extension), using the hand parallel to the ground as a zero point.
2. Index / Middle Finger Bend Differential
   a. Again using both fingers parallel to the ground as a zero point
   b. Flexing one finger while extending the other (reversing creates the opposite effect – movement of that BEAR DOF in the opposite direction.

iGlove Functionality

The iGlove comprises six 3-axis accelerometers and one USB microcontroller. One accelerometer lies on each fingertip, and one is positioned on the back of the hand (as part of the microcontroller PCB – see figure below). The accelerometers can measure both acceleration magnitudes and static orientation (hence the ability to recognize both the static "halt" hand signal to enable control and the ability to recognize a hand shake to disable control – see Mode Switching mappings above).

Therefore, the iGlove has a total of 18 measurable degrees of freedom (DOF). However, for the testing at Fort Benning's Maneuver Battle Lab, only 3 DOF were used (palm pitch, index finger pitch, and middle finger pitch).

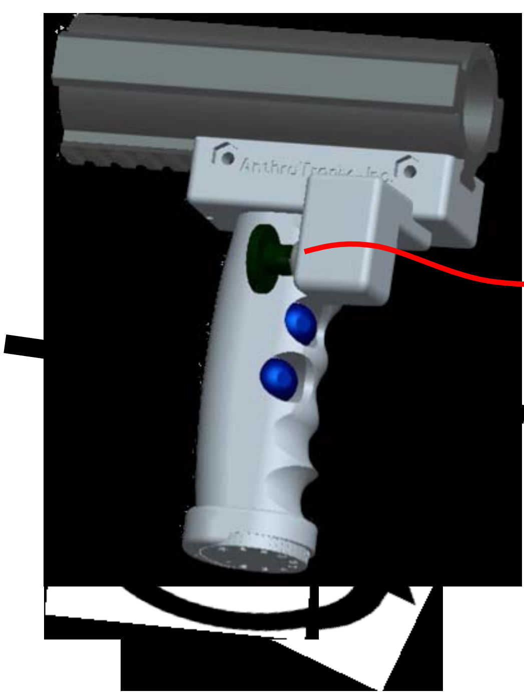
Figure 11. AnthroTronix updated iGlove.

Mounted Force Controller (MFC)-BEAR Mappings – Movement (Cave 2)

Via our control algorithm, at any point that BEAR control is enabled, two degrees of freedom (DOF) on each side (left and right) of the BEAR were active (see diagram in the iGlove-BEAR Mappings – Mode Selection section above). This means that, for instance, in Arm Mode, both right and left elbows and wrists could be controlled.

In Cave 2, movement of these DOF was created via input from the Mounted Force Controller (MFC), which attaches to the front rail of a standard weapon rail, replacing a front pistol grip. To provide the control inputs, the soldiers had two options: (a) the thumb stick or (b) the vertical grip. Both provided the same inputs; however, the thumb stick moved the selected joints at ½ speed while the vertical grip moved the joints at full speed. Therefore, for example, the vertical grip could be used to navigate to a wounded soldier and then the thumb stick could be used for fine control while picking him up.

Figure 12. AnthroTronix Mounted Force Controller (MFC).



DEGREES OF FREEDOM

Thumb Stick (fine control)
1. UP / DOWN
   Moves active BEAR DOF #1 forward / backward at ½ speed.
2. LEFT / RIGHT
   Moves active BEAR DOF #2 forward / backward at ½ speed.

Vertical Grip (gross control)
1. TWIST
   Moves active BEAR DOF #1 forward / backward at full speed.
2. PUSH / PULL
   Moves active BEAR DOF #2 forward / backward at full speed.

Gamepad-BEAR Mappings (Cave 3)

Mode Switching

- Press and hold button 9 on the controller to enable CONTROL_CHOOSER
- While in CONTROL CHOOSER mode, press various buttons to select a mode to switch to
- Release button 9 to execute control mode selection
- example: to select DRIVE CONTROL mode:
  press and hold button 9, press and release button 1, release button 9

Drive Control

Drive Instructions:

1. press and hold one of buttons 5, 6, 7, or 8 to choose a drive speed
   - While holding down the selected button:

     a) use the right analog stick to drive the Bear forwards, reverse, and to rotate it, with analog control

     _OR_

     b)use the directional pad to drive the Bear forwards, reverse, and to rotate it, with digital control (full speed in the direction pressed)

Joint Control

Joint Actuation Instructions:

- press & release buttons 5/7 (left) and 6/8 (right) to cycle through the left/right side active joint
- move right analog stick up/down to increase/decrease the velocity of the selected right joint
- move left analog stick up/down to increase/decrease the velocity of the selected left joint
- press up/down on the directional pad to increase/decrease the maximum velocity limit

Appendix B – TATRC OASIS Demonstration

TATRC OASIS Demonstration
16-17 June 2009
Fort Detrick, MD

AnthroTronix participated in the TATRC OASIS demonstrations in June 2009, demonstrating iGlove and control of a simulated, JAUS-compliant BEAR robot. Images from the demonstration are below.

Figure 13. TATRC OASIS demonstration site.

Figure 14. iGlove controlling BEAR arm joints.

Figure 15. iGlove navigating BEAR.

Appendix C – Project Personnel

AnthroTronix personnel contributing to this effort include:

- Mr. Jack Vice, Principal Investigator
- Dr. Cori Lathan, PhD, Research Advisor
- Ms. Charlotte Safos, Personnel Manager
- Mr. Jonathan Farris, Software Engineer
- Mr. James Drane, Project Manager